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Georgia Institute of Technology
Textile and Fiber

Variable Speed Controller

Ergonomics

Ergonomics is one of the major forces necessitating the need for a new variable speed controller. According to the Georgia Tech Research Institute (GTRI) Economic Development Laboratory report, approximately 30% of the seated apparel workers surveyed reported discomfort in the upper leg, the knee, and the lower leg. Of the standing apparel workers, greater than 45% of the people reported discomfort in the left foot and 36% - 45% reported discomfort in the right foot. According to Mike Kelly of GTRI, this can be attributed to the operators placing all of their weight on one foot and then using the other foot to operate the treadle.

Other ergonomic factors that had to be considered were the length of a person's foot, the angle at which the foot is turned out normal to the body, the pressure exerted by the foot, and the force that could be used to turn an object.

It was found that the average length of a woman's foot is 228 mm with a standard deviation of 11 mm. The 95% female right foot is 258 mm. The 5% right foot length is 223 mm. The area that the foot covers is 89 cm^2 with a standard deviation of 10 cm^2. There is not a statistical difference between the left and right foot. A man's foot was approximately 32 mm longer and it covers 19 cm^2 more. The 95% male right foot is 288 mm. The 5% male right foot is 240 mm.

The average angle at which the right foot is turned out, a position normal to the body, is 6.80° with a standard deviation of 5.10. A man's foot is turned out 2.30° more than a woman's. It was also found that one can turn his left foot out farther than the right foot. A typical person can rotate his right foot clockwise 50° and counterclockwise 45°.

The pressure exerted by the female foot averages .33 kg/cm^2, with a standard deviation of 0.052. The least pressure exerted was 0.27 kg/cm^2. S. Konz and V. Subramanian determined the pressure data by dividing the body weight in half and then dividing by the contact area. The pressure in lbs/cm^2 is 0.727. For a woman, this translates into an average force of 64.748 lbs exerted by each foot.

According to Woodson and Conover, the upper-force limit for hip movement only is 40 pounds. It is possible to develop a CTD (cumulative trauma disorder) in the hip if the force of the motion involved is greater than 40 pounds. According to Mike Kelly of GTRI, there is no hard evidence to back up the possibility of CTD's occurring yet, but logical thought processes would lead one to this conclusion.

Occupational Safety and Health Administration Requirements

The foot controller must follow Occupational Safety and Health Administration (OSHA) Regulations. These regulations are stated in the Code of Federal Regulations published by the executive departments and agencies of the federal government. The following regulation is located in the labor Code of Federal Regulations.

> Labor 1910.217 (4) Foot pedals (treadle). (i) The pedal mechanism shall be protected to prevent unintended operation from falling or moving objects or by accidental stepping onto the pedal. (ii) A pad with a nonslip contact area shall be firmly attached to the pedal. (iii) The pedal return spring(s) shall be of the compression type, operating on a rod or guided within a hole or tube, or designed to prevent interleaving of spring coils in event of breakage.

Presently there are no OSHA standards concerning ergonomics. However, the federal government is in the process of making ergonomic standards in order to improve working conditions for employees.

Design Process

After the initial problem was discussed, a brainstorming session took place. Information on ergonomics was gathered from GTRI. A consultant in the apparel industry was contacted to discuss modular apparel manufacturing. The Georgia Tech data bases were used to find books on different types of controls. From this information gathered, the alternatives were narrowed down to five. The five remaining were

1) lasers, 2) vacuum or air flow, 3) roller bar, 4) push bar, and 5) pressure sensors in the floor.

The laser could control the change in needle speed by determining the number of beams broken by the operator's leg. The operator could move his leg forward into the path of the beams. Ergonomically, this design had its advantages. Weight could be distributed on both feet. The operator's motion would be forward as he/she started to place the fabric into the sewing machine. There would be little trouble with operator safety. The major disadvantages to this design were the space necessary for its use and the trip hazards developed by the receptors for the lasers.

The vacuum or air flow idea was very similar to the laser idea. As the air receptacles were covered, the speed of the needle would increase. The operator would step into the air flow. Ergonomically, there was little problem with this design. The operator would be able to maintain weight on both feet. The operator's motion would be in the forward direction as he/she started the needle and pushed the fabric into the sewing machine with a forward motion. There would be little trouble with operator safety. The major disadvantages were the same as those for the lasers.

The idea of using a push bar with the thighs is similar to the knee press that is already on the market. As the bar is pushed in, the needle speed would increase. Ergonomically, this design had few disadvantages. Weight could be distributed on both feet. The operator would be able to use either leg or both legs to operate the machine. The operator's motion would be in the forward direction as he/she started the needle and pushed the fabric forward into the sewing machine. The major disadvantages with this design were the possible hazards from having a bar sticking out and the construction of a fail-safe switch.

The idea of the roller bar is similar to a computer mouse. As the mouse is moved in a normal forward direction, the needle speed would increase. A spring mechanism would be installed so that weight could be distributed to the foot operating the control. Ergonomically, this had some disadvantages. The constant rolling of the pedal, if directed from the hip, could cause hip problems. The operator's motion would be in the forward direction as he/she started the needle and pushed the fabric forward into the sewing machine. The major disadvantage to this design is the possibility of the operator tripping due to the rolling motion of the bar.

The pressure rug alternative would increase or decrease the speed of the machine depending on where the operator is standing on the rug. Ergonomically, there were no disadvantages to this idea. There would be an anti-stress mat or carpeting for the operator to stand on. The operator would be able to maintain even weight on both feet. The sensors could be placed so that the operator's motion would be in a forward direction as he/she started the needle and pushed the fabric forward into the sewing machine. The major disadvantage of this design was the precision needed to reach the desired speed.

A trip to Southern Tech to visit the apparel laboratory resulted in the observation of several types of controllers. The design group discused the controllers presently on the market and the controller alternatives with Carol Ring. The design group used her expertise in re-evaluating the design alternatives. Lasers and the vacuum or air flow seemed to be over-engineered. The roller bar would be too great a safety hazard, and the push bar would get in the way of the fabrics being processed. This left the pressure rug.

The pressure rug needed to be more precise, so the design group went back to the decision matrix to discover ideas that could be combined with the pressure rug to get precision. The idea of a disk that could be turned by the foot seemed to work, but pressure sensors did not apply. Carol Ring was asked to evaluate the design. After a discussion with her and with Dr. Dorrity and Mr. Brazell, it was decided to proceed with the design of a disk placed in an anti-stress mat.

Design Analysis

The final design is based on a disk that will rotate no more than 15°. This rotation will activate a potentiometer, which will change the voltage; this in turn will change the speed of the needle. The disk will be placed in an anti-stress mat to help alleviate strain on the body. The actual design is described in detail in the Foot Controller Design section. A working model was built to simulate the designed model. Details of the working model are in the Model section.

The Controller Design

The general design consists of three parts: the base, the pedal, and the potentiometer.

The base is a polyisoprene rubber that provides excellent resiliency, durability, and chemical resistance. The resistance includes the ability to resist moisture and dirt as well as more dangerous chemicals. This type of rubber also provides an easy surface in which to cut and to mount the other pieces. The mat is 35 inches wide and 24 inches long. The base height is 2 inches. The corners of the base are rounded to prevent a trip hazard. The size of the base should allow it to be placed anywhere in front of the machine that the operator wishes. This alleviates the problem associated with the treadle used now. The treadle used currently can not be adjusted due to its height and its need for mounting.

The pedal is made of aluminum and is mounted with bearings to support the load as well as to provide easier turning of the pedal. The pedal is shaped like a human foot for easy placement of the operator's foot. There is a guard attached to the right side of the disk that will aid the operator in the movement of the pedal and the placement of the foot. This guard provides a greater area for the rotational force to be directed. The guard is made of aluminum. A rotational spring provides the force to rotate the disk back to the neutral position. The rotational spring is made out of music wire ASTM-A228. The bearings turn on a track of stainless steel to reduce the friction and abrasion wear between the rollers and the rubber of the base. This track is known as the roller guide. The pedal is placed on the mat so that the operator has room to place his/her left foot on the mat also. The pedal has a radius of 13 inches. The outer edge of the pedal has a turn of 350. The pedal rotates under the edge of the mat. There are dust sweeps on the edge of the mat to prevent dust particles and thread from getting inside the controller.

The potentiometer is connected to the disk by an aluminum rod. The rod is attached to the disk and as the disk turns, the rod turns the potentiometer. The disk can not turn unless 15 pounds of force is placed on the heel area. There is a spring placed under the heel that is rated for 15 pounds force. The spring is 7/8 of an inch in diameter. When the 15 pounds force is met, the shaft can engage and the pedal can rotate. The shaft is 1.75 inches deep. Underneath the shaft is a disk which prevents the shaft from digging into the rubber. The potentiometer is turned by the motion of the foot pedal. The potentiometer provides a voltage that varies from 0 to 20 volts. This in turn feeds the circuit connected to the servo motor. The circuit on the sewing machine allows certain settings to add resistance to the circuit. This limits the current going to the motor. The variable resistance within the circuit of the microprocessor allows for speed control separate from that of the foot pedal. It allows the ability to sew many types of items with a smaller risk of mistakes.

Materials List:

Mat	Rubber
Pedal	Aluminum
Guard	Aluminum
Shaft	Aluminum
Disk	Stainless Steel AISI 304
Roller Guide	Stainless Steel AISI 304
Rollers	Stainless Steel AISI 304
Shaft Spring	Music Wire ASTM-a228

Model

The model consists of three basic parts, the base, the pedal, and the potentiometer controller. The base is made of plywood with one-inch dowels attached as stops and as the axis of rotation for the foot pedal. The foot pedal is a fourteen-inch radius, 25° arc piece made of plywood. An aluminum rod is attached to both the potentiometer and the pedal. This rod changes the potentiometer and it also allows the needle-up action and automatic thread cut to take place. The controller is a standard part obtained from the JUKI research facility in Duluth, Georgia. The part is a series of four potentiometers linked together to add and subtract their voltages to obtain the desired ranges. The voltages are processed by the microprocessor of the sewing machine. This process changes the current being received by the servo motor, thus changing the speed of the sewing machine.

The pedal can lay flat against the base or be mounted on rollers. The stop for the left side would be moved back to provide the necessary range for these functions to take place. The rod could also be the spring for the device if a different potentiometer from the standard JUKI part was used.

Hazards

Several hazardous conditions had to be considered in the design of the foot controller. The following hazards were addressed: tripping on the mat, tripping on the actual controller or disc, electric shock, spills, and the sewing needle.

One requirement of the design is that it must be fail-safe. This requirement was attained by using a tension spring to place the disc back in the neutral position. The shaft under the heel has a cutaway area that allows the disc to move when at least 15 pounds of force is applied. A 15-pound rated spring will be located under the heel.

Another hazardous condition that needed to be addressed was the mat in which the foot controller is embedded. This is raised off the floor enough to be considered a tripping hazard by OSHA regulations. This hazard can be alleviated by painting the area surrounding the anti-stress mat a bright yellow color. This is required by OSHA Regulation 1910.144(a)(3). Sloping the edges of the mat to the floor and rounding the corners will also help.

Tripping over the actual foot controller in the mat can also be a hazard. Therefore, the controller is flush with the floor when inactive, and at least 15 pounds force is necessary for the disc to move.

In order to prevent electric shock, the disc is made of an insulating material. The material of choice is aluminum.

The needle on an industrial sewing machine is a potential hazard. A tension spring is used to return the disc to the neutral position so that the needle does not remain in the up position. Therefore, the needle will not be active when the foot is not on the disc. Also, sewing machines presently have a thumb guard to prevent fingers from getting under the needle.

Possible oil spills and other liquid spills had to be addressed. The rubber mat would need channels in it to allow the liquid to drain to a level lower than the foot until cleanup can take place. The aluminum disc would have a nonslip contact area attached to it. This is required by OSHA Regulations 1910.217 (4) (ii).

Possible Applications

Throughout the design process, other applications besides an industrial sewing machine were considered. Some other possibilities are to use the variable speed controller on any turning operation such as a lathe or a pottery wheel. It could also be used on any motorized vehicle. The gas pedal on a car or truck could be replaced. This had definite possibilities with the upcoming production of electric cars. However, a larger potentiometer would be needed because the required voltage variation would be much larger. The controller could also be used on vehicles such as power boats, lift trucks, and the lunar rover.

Conclusion

A variable speed controller was needed which would allow an operator to control the speed of a needle when the operator was in a standing position. An attempt was made to make the controller more ergonomically sound than the foot treadle normally used in a sit-down sewing operation. Whether or not the new controller was ergonomically more sound could be proven only after a testing period.

The final design consists of a disc that rotates clockwise and counterclockwise placed in an anti-stress mat. When the disc is rotated, a potentiometer is turned by a rod connected to both the potentiometer and the disc. The change in the turns on the potentiometer changes the speed of the needle. The controller can not operate unless 15 pounds of force is placed on the spring under the disc. The compression spring also acts as the return mechanism for the disc. Two bearings are placed under the disc approximately where the ball of the foot would rest.

Cleaning the controller after each shift is recommended. A thorough blowing off of lint, thread, and dust will help to prevent mechanical downtime. It is also recommended that oil dropped on the mat be wiped off as soon as possible.

One design recommendation is to change the shape of the disc to optimize the operator's comfort and to reduce the open area on the mat. Another recommendation is to find a rubber that is either porous or one that has better resistance to oil. This would eliminate the problem with the isoprene rubber's poor resistance to oil. The design could also be amended to include two potentiometers and a switch that would allow the operator to use either the right or left foot. Our final recommendation is to place the mat and controller in the floor to prevent a tripping hazard if a new facility is being constructed or if a facility is being remodeled.

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